4.0 BUILDINGS AND OPERATIONS

This section provides a more detailed description of the site buildings (Section 4.1), an overview of the operations that take place within those buildings (Section 4.2), a listing of the materials handled on site and their characteristics (Section 4.3) and details regarding the safety design features of Building 2 (Section 4.4).

Astrotech provides facilities and limited facilities support for the final assembly, inspection, and processing of payloads prior to launch. Payloads can be grouped into four generic classes of satellites based upon their function: communications satellites, remote sensing satellites, weather satellites, and scientific experiment satellites. Payload processing begins at Astrotech once the satellite and its specific ground support equipment arrive at the site.

The activities which comprise the preparation of the payload for flight can be grouped into non-hazardous and hazardous operations. The non-hazardous activities generally include:

- Final assembly or buildup of the spacecraft;
- Leak tests and initial checkout of propellant systems before propellant loading;
- Installation of solar panels, antennas, insulation and other equipment;
- Payload function testing;
- Inspection and cleaning;
- Monitoring and checkout of payload electronic systems via hardlines and microwave communication.

Operations are designated as hazardous by NASA and the Air Force when significant amounts of potential energy are present and loss of control could result in injury to personnel or equipment; a significant change (i.e., increase or decrease) in the ambient conditions of temperature, pressure, or oxygen content could occur; or the presence of hazardous materials presents the potential for personnel exposure.[1]

The procedures and operations that are considered to be potentially hazardous to personnel or to pose potential damage hazards to critical spacecraft equipment and/or systems, generally include:

- Transport, short-term storage, sampling and loading of liquid propellants (anhydrous hydrazine, monomethyl hydrazine, and nitrogen tetroxide);
- Installation of explosive devices used in space to ignite motors and to separate the payload from the vehicle;
- Final assembly, lifting, and mating of solid rocket motors and liquid propellant motors with the payload;
- Dynamic spin balancing of the assembled payload or the fueled parts of the payload; and
- Transport of the fueled spacecraft from Astrotech to KSC (See discussion of transport in Section 5).

Payloads have various types of motors that are fueled with either solid or liquid propellants. See Section 4.2.1 for a discussion of the functions of various motors. The orbit position control propulsion system in the spacecraft itself can use either a single liquid fuel referred to as a monopropellant (i.e., anhydrous hydrazine) or a combination of liquid fuel and liquid oxidizer referred to as bipropellant (i.e., monomethyl hydrazine and nitrogen tetroxide) depending on the requirements of the spacecraft. Generally, both the perigee kick motor (PKM), when required, and apogee kick motor (AKM) contain solid propellant. Monopropellant spacecraft usually use a solid propellant AKM; however, in bipropellant spacecraft the AKM often utilizes the same liquid bipropellants as the orbit control propulsion system. Thus, a fueled spacecraft can have, in addition to solid propellant, combinations of liquid fuel and liquid oxidizer: (1) anhydrous hydrazine only, or (2) monomethyl hydrazine plus nitrogen tetroxide.

4.1 Payload Processing Buildings

The buildings in the hazardous and non-hazardous work areas on the Astrotech site are physically separated by a distance of approximately 335 feet. See Exhibit 4-1. This physical separation ensures that the hazardous work areas are located beyond the distance required by explosive siting criteria. See Section 7.1.1. A typical spacecraft is located first in Building 1, the non-hazardous processing facility, for operations such as electrical systems checkout and leak check and then moved to Building 2, the hazardous processing facility, for operations such as propellant loading.

4.1.1 Building Descriptions - Non-Hazardous Areas

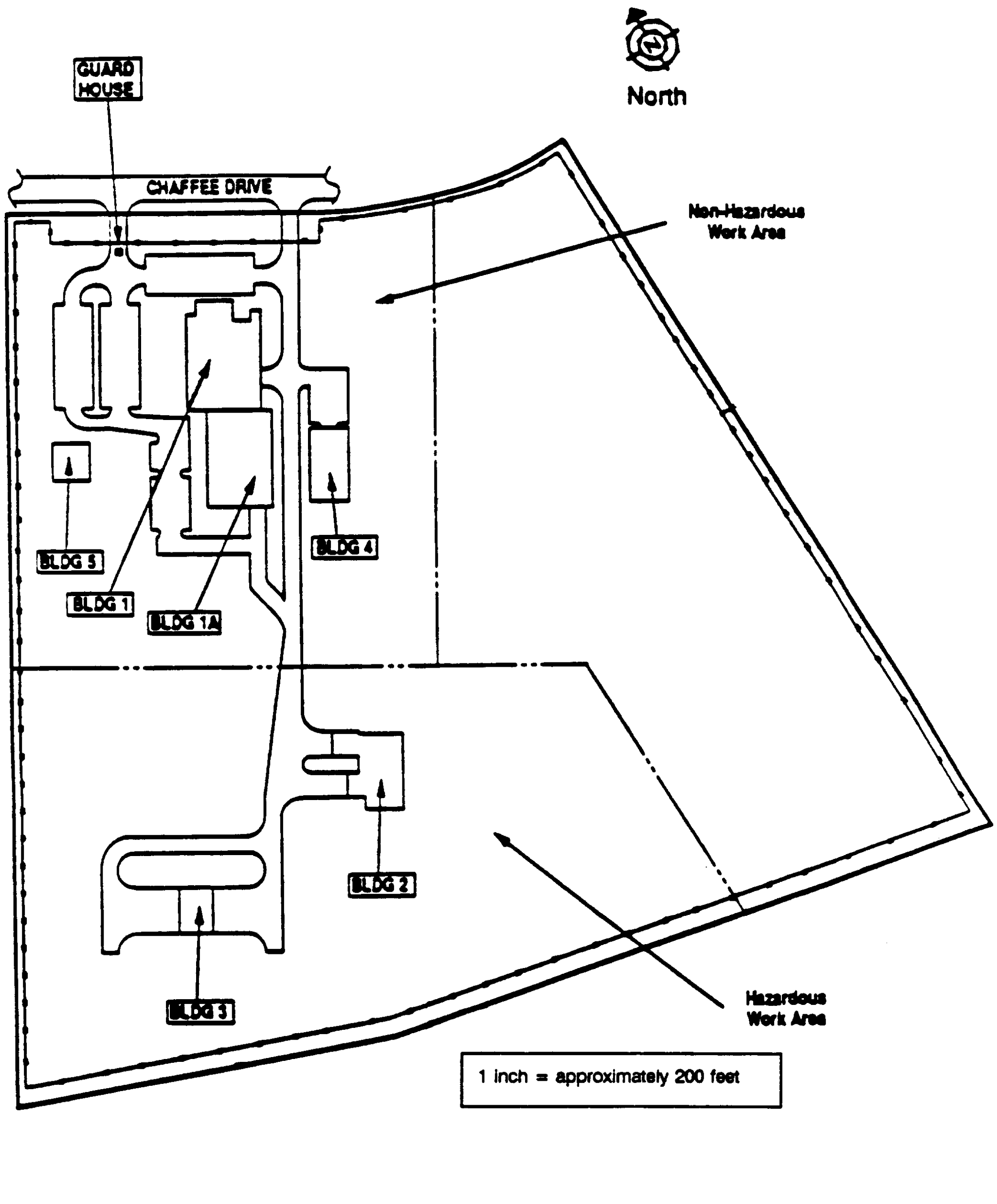
Buildings 1 and 1A

Buildings 1 and 1A are separate but adjoining buildings that comprise the non-hazardous processing facilities. Building 1 with dimensions of 136 feet x 193 feet x 53 feet (including roof top air conditioning equipment) contains three payload processing high bays, a common clean room airlock and

[1] Space Transportation System Payload Ground Safety Handbook, SAMTO HB S-100, KHB 1700.7, November 1982, p 4-2.

associated support office space. The building has three antenna towers on the rooftop, 96 feet above ground, that enable direct line-of-site air links with nearby launch complexes at KSC and CCAFS.

EXHIBIT 4-1 SEPARATION BETWEEN HAZARDOUS AND NON-HAZARDOUS FACILITIES



Building 1A, the later addition, contains one clean room high bay with its own clean room airlock. The overall building dimensions are 95 feet x 170 feet x 60 feet. Both buildings are constructed of steel columns and beams with metal stud framing, except for the office and support sections of Building 1, which are of concrete masonry block.

Overhead cranes within Building 1 provide hoisting capability in each high bay, and those within Building 1A provide hoisting capability in and between the high bays and airlock. In addition to the high bays and airlocks, each of the two buildings contains garment change rooms, office areas, conference rooms, break rooms, and an administrative area.

Building 4

Building 4 is the warehouse storage facility. It is used for storage of equipment not requiring a controlled environment, such as shipping containers and certain ground support equipment. Dimensions are approximately 62 feet x 125 feet x 30 feet. It is constructed of corrugated steel sheeting, interspersed with translucent corrugated fiberglass.

Building 5

Building 5 is the customer office building. It is primarily used for client office space during operations. The building is pre-engineered of structural steel and has approximate dimensions of 60 feet x 60 feet x 16 feet.

4.1.2 Building Descriptions - Hazardous Operations Area

Building 2

Building 2, the hazardous processing facility, is used for activities such as liquid propellant transfer operations, installation of ignition and separation ordnance, spin-balancing, and mating of the spacecraft with its upper stage (perigee kick motor or both perigee and apogee kick motors). Since these hazardous operations are the major focus of this evaluation, more details about Building 2 are presented in this evaluation than for other buildings on the site.

Building 2 (approximately 120 feet x 120 feet) contains clean room high bays and airlocks. A system of overhead cranes provides lifting capacity through the building such that a lifted load can be transferred or passed off between cranes and moved between the high bays. The major areas of the building include two airlocks (the North has a ceiling height of 65 feet and the South 43 feet), three clean room high bays, two propellant cart storage rooms, two garment change rooms, and two control rooms. See Exhibit 4-2 for the general layout of Building 2 and Exhibit 4-3 for the room specifications.

EXHIBIT 4-2 LAYOUT OF BUILDING 2

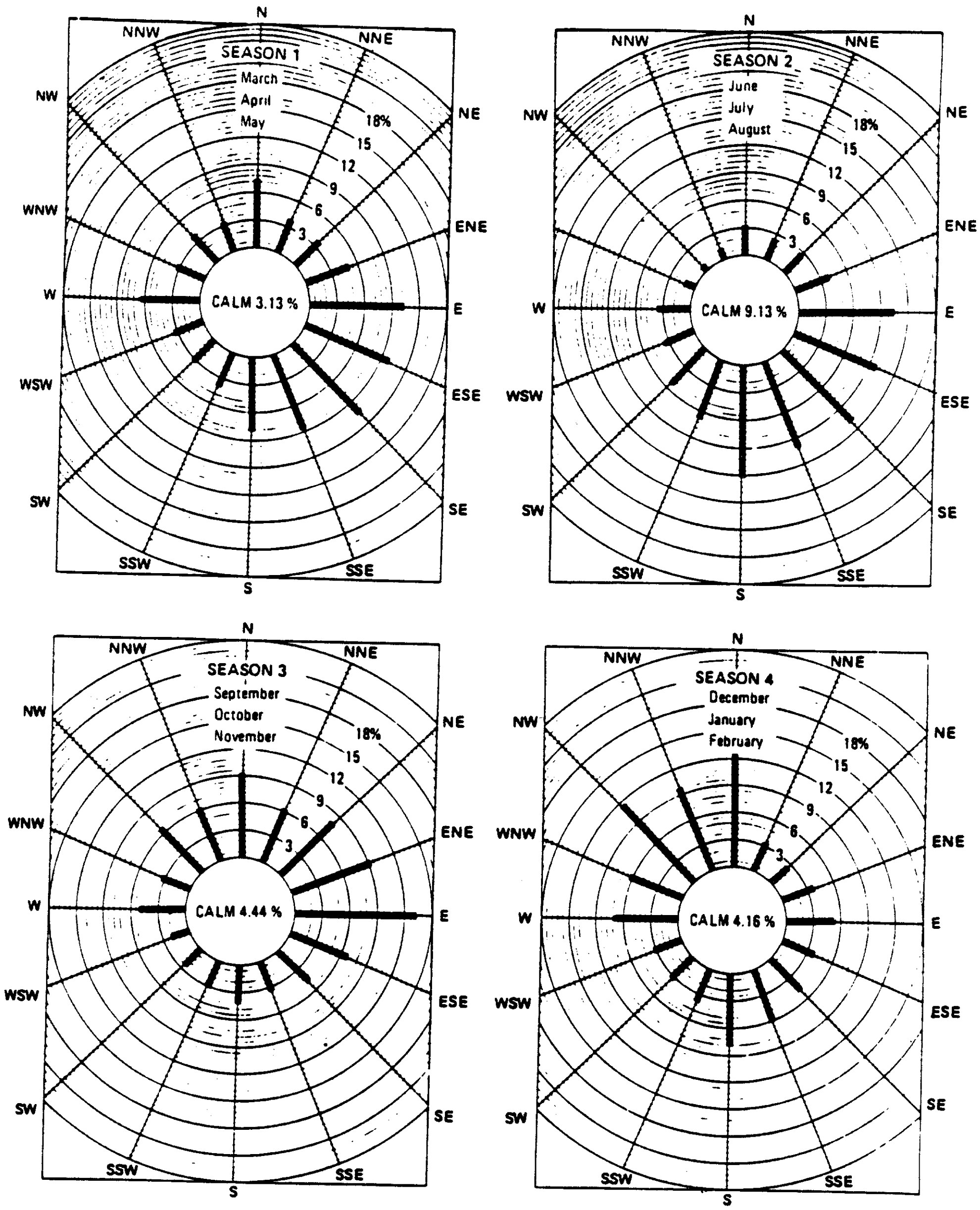


EXHIBIT 4-3 BUILDING 2 ROOM SPECIFICATIONS

RM	FUNCTION	LENGTH	WIDTH	HEIGHT	LARGEST DOORWAY	FLOORS	WALLS	CEILING
101	South Airlock	38	29	43	20x40	Vinyl	GWB	GWB
102	South High-Bay	60	37	43	20x40	Vinyl(c)	GWB	GWB
103	Center High-Bay	48	27	43	20x40	Vinyl(c)	GWB	GWB
104	North High-Bay	60	37	43	20x40	Vinyl(c)	GWB	GWB
105	Office	12	11	9-4	3x6-8	Vinyl	GWB	ACST
108	North Control Room	30	25	9-4	8x8	Vinyl	GWB	ACST
109	North Change Room	20	10	9-4	3x6-8	Vinyl	GWB	ACST
110	Corridor							
111	Women's Restroom							
112	Janitor							
113	Men's Restroom							
114	South Change Room	19	14	9-4	3x6-8	Vinyl	GWB	ACST
115	South Control Room	25	15	9-4	8x8	Vinyl	GWB	ACST
116	Balance Control Room	15	10	9-4	6x6-8	Vinyl	GWB	ACST
118	Corridor							
119	Oxidizer Cart Room	20	20	9-4	10x10	Vinyl	Concrete	GWB
121	Fuel Cart Room	20	20	9-4	10x10	Vinyl	Concrete	GWB
123	North Airlock High-Bay	55	40	65	20x50	Vinyl(c)	GWB	GWB

Notes:
1) All dimensions are shown as feet or as feet-inches
2) Vinyl(c) - Conductive Vinyl
3) GWB - Gypsum Wallboard
4) ACST - Acoustic Tile

Building 2 is sited, designed and constructed to meet explosives safety criteria standards[2,3,4] and permitted to contain up to 2,500 pounds of liquid fuels, 5,000 pounds of liquid oxidizer and sited for 24,600 pounds of solid propellant. The high bays and airlocks are constructed of structural steel column and beams with steel reinforced concrete-filled masonry block. The walls have integral horizontal concrete tie beams and the roof is framed with steel joists and decked with corrugated steel sheeting. The entire building is covered on the exterior by insulation sealed with plasticized cement/stucco for an impact resistant and airtight exterior. The upper surface of the roof has an attached layer of rigid insulation material covered by a heat sealed plastic membrane for thermal and moisture protection. The temperature and humidity inside the clean room (100,000 Class) high bays are monitored and controlled.

There are two grounding grids, one outside the building and one inside, consisting of structural steel ground bars connected to a steel grate in the floor. All lights and intercoms are purged by positive air flow out of each device to prevent the possible ignition of any flammable vapors that might be present in the high bays. All other electrical equipment in the high bays is explosion-proof.

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[2] Bureau of Alcohol, Tobacco, and Firearms, Department of the Treasury, ATF P 5400.7 (11/82).

[3] DoD Directive 6055.9, DoD Ammunition and Explosives Safety Standards, July, 1984.

[4] Department of the Air Force, AFR 127-100 CHANGE 1, 24 December 1984, Chapter 8 - Site Plans, Construction, and Utilities, Section A - Explosives Site Planning and Section B - Construction Considerations.

Building 3

Building 3 is a storage facility designed for short- or long-term storage of payloads, SRMs, flight hardware, ground support equipment or other sensitive equipment. Any stored payloads are, in general, waiting for processing. The building contains six identical storage bays which are environmentally controlled but are not clean rooms. Since this building is used for the storage of SRMs, it is designed to DoD and ATF explosives safety criteria and sited in the hazardous work area of the Astrotech site, remote from the other buildings.

Building 3 was designed to store three PKMs called Payload Assist Module (PAM) solid rocket motors (Thiokol Star 48 or Star 63) and three smaller unspecified solid rocket AKMs (typically Thiokol Star 15) all using DoD Class 1.3 (mass-fire) solid propellant. Total propellant quantity limit is 24,600 pounds. No liquid propellants are permitted in the building.

4.2 Hazardous Operations

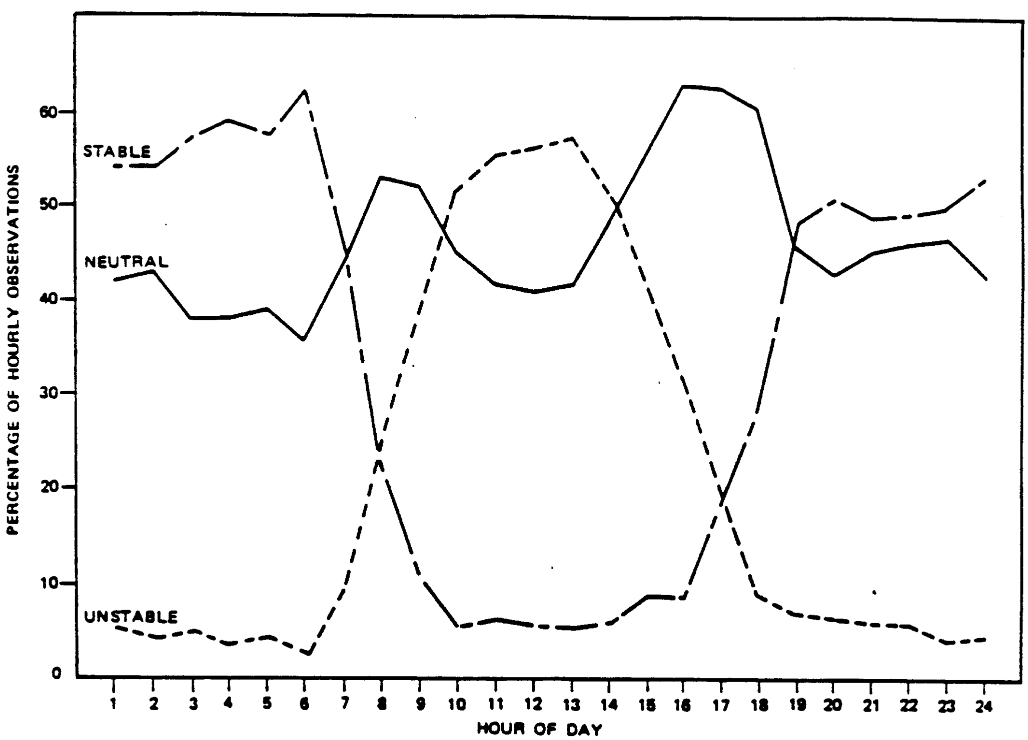
Payload processing operations are comprised of a set of activities that are performed on a spacecraft or satellite and assist motor(s) to ensure that the payload is flight-ready before it is mated with the launch vehicle at the launch pad. Most payloads processed at the Astrotech facility have similar functional characteristics but vary in size and appearance. Variations in size and appearance may mean that the sequence of operations differs somewhat for each payload processing operation. Under typical processing conditions, a spacecraft will be located in the non-hazardous work area (Buildings 1/1A) for 6-10 weeks and in the hazardous work area (Building 2) for 3-4 weeks. Liquid propellant loading is one of the last operations performed. The discussion below describes the "typical" sequence of operations.

4.2.1 Functions of Payload Motors

A typical payload is a communications satellite that needs to be placed in a geostationary orbit 22,000 miles above the earth. Launch vehicles provide only enough energy to boost a satellite into a lower orbit, either a circular one with a diameter of approximately 130 miles, or an elliptical orbit with its low point at about the same altitude. To be fully operational, a typical satellite requires additional energy for three functions: first, to raise the orbit to the 22,000 mile high geosynchronous altitude; second, to circularize the orbit at that altitude; and third, to maintain the precise orbit positioning (i.e., station keeping) throughout the seven to fifteen year operational life of the satellite.

The substantial energy initially required to raise the orbit to the geosynchronous altitude is normally provided by a PKM, which is generally an SRM ranging in size from 4 to 8 feet in diameter. As shown in Exhibit 4-4, the PKM is a separate section of the spacecraft, designed to separate from the remainder of the payload after the PKM's energy is expended. The fairing is a shroud used to surround and protect the spacecraft during ascent through the

EXHIBIT 4-4 SCHEMATIC DIAGRAM OF A TYPICAL PAYLOAD



atmosphere and is typically jettisoned prior to achieving orbit as soon as the launch vehicle has escaped the dense atmosphere.

When the satellite arrives at the required apogee altitude, the additional energy required to circularize the orbit and to adjust the equatorial inclination to place the satellite into its operational orbit is provided by an AKM, generally solid propellant, and sometimes augmented by small motors using liquid propellant(s). Because during its typical operational life of 7 to 15 years a satellite will drift slightly out of the required precise orbit, energy is needed to reposition the satellite periodically. This energy is provided by the small liquid propellant(s) motors. To improve operational efficiency and reliability, the tendency in recent years has been to design liquid propellant rocket systems that can perform both the AKM function and the orbital position control function. Although this design avoids the need for a solid rocket AKM, the amount of liquid propellants required increases significantly.

4.2.2 Typical Payload Processing Operations

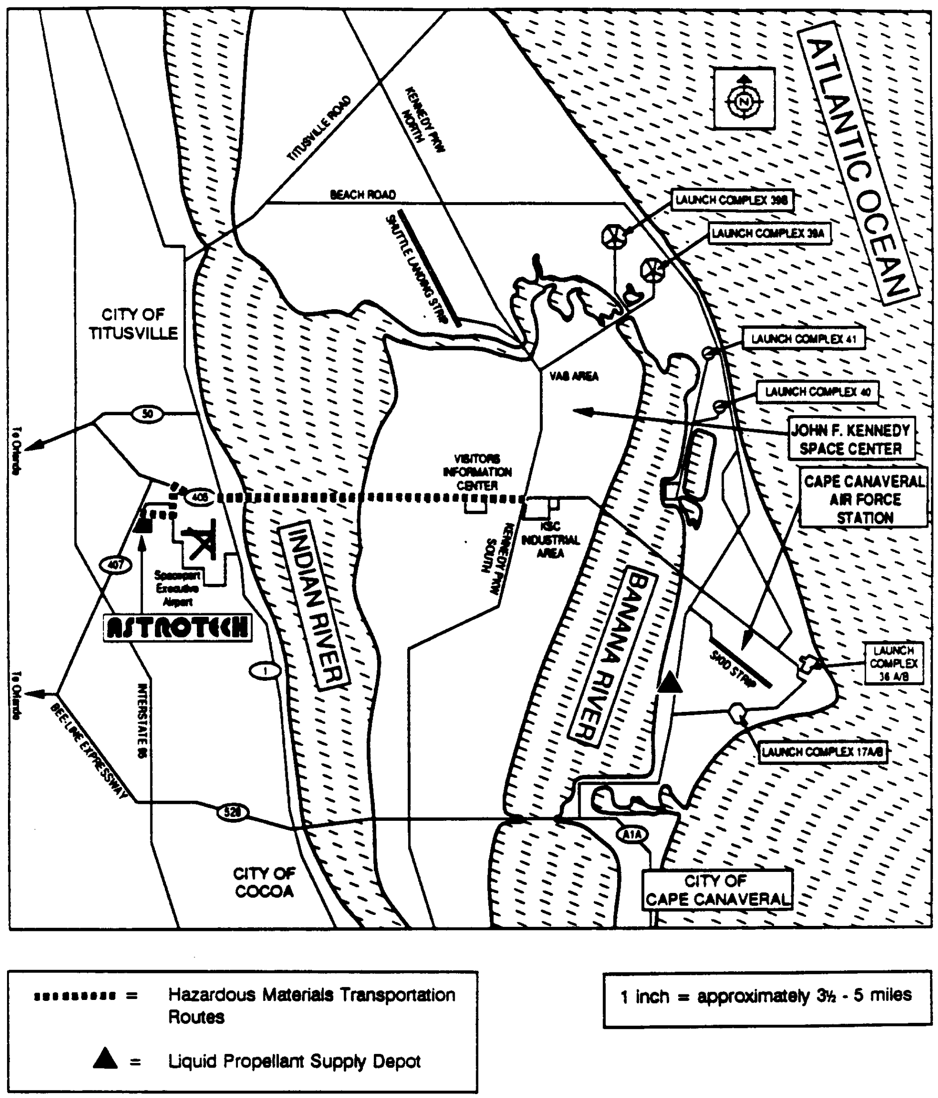
Because the PKM is essentially separate from the rest of the payload, operations at Astrotech can be performed independently on the PKM and the remainder of the payload. Because the PKM has solid propellant and igniter systems, PKM operations are considered hazardous and performed in Building 2. In the typical sequence shown in Exhibit 4-5, the PKM operations begin approximately two weeks before the spacecraft operations and take approximately six weeks to complete. Upon completion of the PKM processing, it either remains in a high bay separate from that used for the spacecraft operations, or it is moved to Building 3 for temporary storage. Simultaneous to the PKM operations, the satellite undergoes approximately four weeks of non-hazardous final assembly and checkout in Building 1, including tests to verify the proper functioning of all electrical systems and leak checks.

As late as possible in the schedule, the liquid propellants are transported from KSC to Building 2, where they undergo thermal conditioning and helium saturation for several days. Operations are sequenced carefully so that completion of PKM operations occurs several days before completion of the non-hazardous satellite processing operations, leaving Building 2 available for liquid propellant conditioning. After the propellants are conditioned and thoroughly saturated with helium, the satellite is moved from Building 1 to Building 2, where the liquid propellants are loaded and any solid propellant AKM installed. (For the "typical" sequence illustrated in Exhibit 4-5, no separate AKM is installed in the satellite.) If the laoded satellite requires dynamic balancing, a spin balance operation is performed at this point. The final step in assembling the payload is to mate the satellite with the PKM. Before transporting the flight-ready payload to the launch pad, the payload is either encapsulated in the launch vehicle fairing or placed in a special container designed to protect the payload during transport.

4.2.3 Transport of Fueled Spacecraft

The transport of the fueled and processed spacecraft from Astrotech to KSC may be considered a hazardous operation. It is performed under strict requirements: a convoy of law enforcement officials accompanies the shipment

EXHIBIT 4-5 TYPICAL SEQUENCE OF PAYLOAD PROCESSING OPERATIONS



in a rolling roadblock (one vehicle is ahead of the transporter and one is behind); the highway intersections are closed to the public ahead of the transport vehicle; transport only occurs at night; and a maximum speed of 5 mph is maintained while en route.

During the course of gathering data on the various processing operations at Astrotech, the evaluation team identified the transport of fueled spacecraft as an area where, despite the fact that it is beyond the scope of this evaluation, additional coordination was indicated between Astrotech and RSPA to ensure compliance with all requirements of the Hazardous Materials Transportation Act. Astrotech acted quickly on the verbal recommendation of the team to coordinate with RSPA and provided all technical information identified by RSPA to obtain the transportation approvals called exemptions for the transport of not only the fueled spacecraft but also propellant carts, when needed, propellant samples, and the oxidizer filter assembly.

Astrotech transports fueled spacecraft under this approval from the U.S. DOT. Prior to transport, Astrotech obtains an oversize load permit from the Florida DOT, and a Florida DOT officer inspects the transport equipment, procedures, and driver licensing records to assure full compliance with all applicable federal and state laws and regulations. This Florida DOT officer also accompanies the transport convoy. Refer back to Exhibit 3-7 for transport routes.

4.3 Characteristics of Hazardous Materials

The hazardous materials handled at the Astrotech facility of most interest are chemicals used in the propulsion system(s) of the spacecraft (both liquids and solids) and ordnance (electroexplosive devices [EEDs]) used to ignite SRMs and to separate the spacecraft from assist motor(s).

The liquids used as propellants are two types, fuels and oxidizer. These chemicals are stored and handled at ambient conditions without elevated pressures or reduced temperatures. They are very volatile and when they come into contact with one another they spontaneously ignite, liberating large quantities of heat and gas. Because they undergo this reaction (referred to as a hypergolic reaction), these chemicals are extremely useful as rocket propellants. The fuels used at Astrotech include anhydrous hydrazine (AH) and monomethyl hydrazine (MMH); they are also referred to as hydrazine fuels. The oxidizer is nitrogen tetroxide (N_2O_4). A particular spacecraft may require only fuel (i.e., monopropellant system) or both fuel and oxidizer (i.e., bipropellant system).

As detailed below, these chemicals are used in other industries besides the space industry and have been manufactured, transported, stored, and handled safely for many years. For an overview of releases of hydrazines and nitrogen tetroxide reported to the National Response Center (NRC) over an 8-year period, see Appendix B. In the eight year period, there were 77 separate releases of hydrazine and 66 of nitrogen oxides. Of the hydrazine releases, 35% were attributable to public utilities and only 9% were space industry related. Of the nitrogen oxide releases, 74% were attributable to manufacturing industries and only 10.6% were space industry related. Although there have been space industry related releases, the safety evaluation team is not aware of any occurring from payload processing operations.

The major hazards from propellants result from their flammable and reactive characteristics. However, propellants have properties similar to other hazardous chemicals which are routinely transported throughout the U.S. on the nation's highways and are manufactured and used in a variety of industrial operations. For example, liquified natural gas and propane pose similar flammability hazards, and are commonly used for home heating and electricity generation. A typical industrial pressurized spherical propane storage tank contains approximately 475 tons of propane with a chemical energy of 19 x 10^9 BTU. By comparison, a Titan III ELV, one of the largest users of liquid propellants in the spacecraft industry has a roughly equivalent weight, 414 tons, but lower chemical energy, 1.7 x 10^9 BTU. In fire situations, the greater the chemical energy available, the greater the potential hazard. The payloads processed at Astrotech have a much lower quantity of propellants than ELVs, and hence much less chemical energy. Other industrial chemicals, such as chlorine, ammonia, and sulfuric acid pose similar short-term exposure hazards.

4.3.1 Hydrazines[5]

The hydrazine chemicals most commonly used at Astrotech are MMH and AH. Both are clear, oily, water-white liquids with a fishy odor. They are slightly less dense than water. Vapors from these fuels are more dense than air and therefore tend to hug the ground.

The largest manufacturers of hydrazine in the U.S. are Olin Chemicals (approximately 21 million pounds per year), Mobay (14 million pounds per year) and Fairmont Chemical (1 million pounds per year). Total U.S. production averages around 36 million pounds annually, of which 29 million is sold commercially. The remainder is retained for use by the manufacturer or produced directly under contract. Only 5% of all hydrazine produced in the U.S. is used by the space industry. The greatest consumer of hydrazine is the agricultural chemical industry which uses 40% of the total hydrazine output.

Hydrazine is a key ingredient in a variety of agrochemicals, including many common pesticides, fungicides, algaecides, bactericides and herbicides. Some blowing agents also contain hydrazine, particularly those used in the production of foam rubber and plastics (including certain types of vinyl flooring and automotive cushions). This accounts for another 28 percent of the hydrazine consumed in the U.S.

Only 15% of the hydrazine that is produced in the U.S. is used as pure hydrazine. In this form, it is effective as an industrial water treatment chemical to remove chromates and is also used by electric utilities and other industries to scavenge oxygen from feed water and reactor cooling waters. The remaining 12% that is produced is used as a chemical intermediate in a variety of products and processes. It is a key component of an experimental drug for sickle-cell disease and is also found in the antituberculant drug Isonoizoid. It is used when plating electrolytic metals onto glass and plastics, as an intermediate in textile dyes, as a polymerization catalyst, and as a reducing agent in the extraction of plutonium from reactor wastes. Estazolam, a sedative, and hydrazide salts used in soldering fluxes are also manufactured from hydrazine.

Monomethyl hydrazine is manufactured in the U.S. by Charkit Chemical Corporation in Darien, CT and the Olin Corporation in Stanford, CT. The latest available records show that at least 100,000 pounds were produced in the U.S. in 1977. Since 1982, however, monomethyl hydrazine has not been sold on the commercial market. Monomethyl hydrazine is used as a chemical intermediate, as a solvent, and in the synthesis of the antibiotic cesftriaxone.

Further information on the properties of the hydrazine fuels can be found in the Chemical Propulsion Information Agency (CPIA) Publication 394, Hazards of Chemical Rockets and Propellants, Volumes I, II, and III, Applied Physics Laboratory, Johns Hopkins University, September 1984 and in Hydrazine

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[5] Hypergolic Propellant Hazard Response Guide, Cape Canaveral Air Force Station (CCAFS), Draft Volume I, ICF Technology Incorporated, July 1, 1988.

and Its Derivatives Preparation, Properties, Applications, Eckart W. Schmidt, Wiley-Interscience Publications, USA, 1984.

The hydrazines are volatile chemicals that react readily with carbon dioxide and oxygen in the air and will also decompose on contact with some metals. If hydrazine vapor is released into the air in sufficient concentration, it may ignite or react to form ammonia and oxides of nitrogen (NO_x). Further oxidation will form ammonia-based nutrients and the NO_x will ultimately return to earth as nitric acid rains.

The hydrazines are flammable liquids that can present fire and explosion hazards, if sufficient quantities are handled improperly. A vapor phase is readily formed at ambient conditions (the vapor pressures are roughly that of water) and the vapor can be ignited by spark, open flame, or contact with an oxidizer. Exposure of MMH or AH to air from a large surface, such as saturated rags, may result in spontaneous ignition due to the heat evolved from contact with oxygen in the air.

The hydrazines are also corrosive, poisonous, and can present serious health hazards if direct contact is made with sufficient quantities of either the liquid or vapor. The most severe exposures occur through dermal (i.e., skin) contact with liquid and inhalation of vapors. Contact of the chemical on the skin can cause severe burns and the chemical can enter the bloodstream leading to similar effects caused by inhalation. These effects may include damage to the central nervous system such as tremors, convulsions, or death in the case of extremely high concentrations of the chemical involved. Hydrazine is also a suspect human carcinogen, according to the American Council of Industrial and Government Hygienists. However, since hydrazine decomposes quickly upon release into the atmosphere, it is unlikely that vapor concentrations will remain high enough to cause serious health effects. See Exhibit 4-6.

4.3.2 Nitrogen Tetroxide[6]

Nitrogen tetroxide is a thick, heavy, greenish liquid that is very volatile (its vapor pressure is about 50 times that of water and 5 times that of acetone). Its yellowish to reddish brown vapor, which is due to the nitrogen dioxide (NO_2) resulting from the N_2O_4-NO_2 equilibrium mixture, has a pungent odor similar to bleach. Nitrogen tetroxide is manufactured by a single source in the U.S., Cedar Chemical Corporation in Vicksburg, MS. Based on data from the U.S. Air Force Directorate of Energy Management, Kelly AFB, the annual production capacity for N_2O_4 is estimated to be 3 million pounds per year.[7] Nitrogen tetroxide is produced by oxidation of nitric oxide which is an intermediate stage in the production of nitric acid from ammonia. N_2O_4 is used in the manufacture of other chemicals (e.g., nitric acid and ammonia fertilizer), as a chemical manufacturing intermediate, a nitrating agent, an oxidizing agent, as a polymerization inhibitor for acrylates, and as a catalyst. In air, nitrogen tetroxide liquid will vaporize and dissociate to form gaseous phases of nitrogen tetroxide, nitrogen dioxide, and nitric acid (mist).

Propellant grades of nitrogen tetroxide, which is mixed with nitric oxide, are known as MONs (mixed oxides of nitrogen) and are identified by percent weight of nitrogen tetroxide with no more than 0.17 percent by weight of water. N_2O_4 dissociates into NO_2 which is rapidly photochemically

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[6] Ibid.

[7] Post Accident Procedures for Chemicals and Propellants, AFRPL-TR-82-031, Report F04611-80-C-0046, Systems Technology Laboratory, Inc., September 1982.

decomposed to nitrogen oxide (NO) and oxygen. The typical half life for NO_2 in sunlight is about 2 minutes.[8] Nitrogen oxides react with atmospheric moisture to form nitric acid rain which can be returned to the land during precipitation.

Though not flammable itself, nitrogen tetroxide will support the combustion of most fuel sources. In addition, N_2O_4 may ignite organic materials such as wood or rubber on contact. Nitrogen tetroxide will react with water in a vigorous reaction that will produce nitric and nitrous acids and NO_2.

Contact with corrosive N_2O_4 liquid or vapor may lead to burns of the skin and eyes. Inhalation of a sufficient quantity of N_2O_4 vapor to cause adverse health effects may initially occur without great discomfort; however, a few hours later more severe symptoms of tightness in the chest, coughing, and breathing difficulty may begin and could result in pulmonary edema and death in severe cases.

4.3.3 Solid Rocket Motors

Solid rocket motors (SRMs) contain solid propellant; those handled at Astrotech include PKMs and AKMs. The description below of a "typical" SRM illustrates how it releases energy to perform the perigee and apogee kick, orbital adjustment functions. A typical SRM is mainly rubber-like propellant surrounded by a thin-walled case constructed of heat-treated steel, titanium or glass filament. The forward internal section of the motor consists of a ring of propellant around a star-shaped hollow area. This star configuration greatly increases the available surface area, allowing for easy ignition triggered by the igniter ordnance. The central internal section of the motor has a hollow, smooth circular core. On the end of the aft closure is the nozzle where hot gases exit the motor.

The solid propellant burn travels from forward to aft instantaneously and then from the core outward to the steel casing. Since the propellant burns at over 6,000°F, the thin-walled case must be insulated from the heat. Initially, the unburned propellant contributes to this insulation. For end-of-burn insulation, a layer of insulative material is used between the propellant and the case.

The primary hazard from solid propellant in the SRMs processed at Astrotech is due to its flammability. Solid propellant is classified by the DoD as a Class 2, Division 1.3 (non mass-detonating, mass-fire hazard).[9] The material itself is not explosive; however, a solid propellant produces large volumes of gas upon burning, which can lead to rupture and/or propulsion of the motor. Additionally, the burning of an SRM generates hydrochloric acid, a toxic combustion product.

There are several ways to ignite solid propellant, including: 1) hard impact, caused either by a motor dropping onto a hard, sharp surface from several feet or by an object falling onto exposed propellant or its steel case, 2) direct contact of propellant grain with a flame, 3) extreme heat, 4) an electro-static energy discharge or other large electrical discharge, such as lightning, and 5) activation of explosive destruct charges or the motor ignition system. Inadvertent ignition of solid propellant is difficult when

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[8] Hazards of Chemical Rockets and Propellants, Volume III, Liquid Propellants, CPIA Publication 394, Chemical Propulsion Information Agency, The Johns Hopkins University, Chapter 14 - Nitrogen Oxides, September, 1984.

[9] DoD Directive 6055.9, DoD Ammunition and Explosives Safety Standards, July 1984.

standard safety practices are used. In fact, SRMs segments are regularly transported both by rail and highway carriers, illustrating that they are routinely safely handled in the normal transport environment.

4.3.4 Ordnance

Ordnance is defined in ESMCR 127-1 as all electroexplosive devices, detonators, squibs, primer, pyrotechnic devices, initiators, igniters, solid propellants, explosives, warheads, ammunition, fuzes and energy transfer systems (e.g., linear shaped charges and Primacord). All initiating ordnance items, for example, EEDs, are classified as Category A (hazardous)[10] or Category B (non-hazardous) for pre- and post-installation handling situations. ESMCR 127-1 details safety requirements for EEDs in Section 3.13.4, ranging from design, connection, and environmental criteria (shock, vibration, temperature). The hazards from ordnance are the potential for ignition or detonation.

4.3.5 Other Hazardous Materials

Other hazardous materials used at the Astrotech facility for various industrial support operations (e.g., degreasing parts, paint thinners, and solvents) include isopropyl alcohol, 200 proof alcohol, Freon-113, gaseous helium, high pressure liquefied nitrogen, gaseous nitrogen, and methyl ethyl ketone. The use of these products at Astrotech does not pose a danger to the public.

One Astrotech customer has a leak check procedure that uses helium containing a small amount of krypton-85, a gas that is a source of ionizing radiation. All use of ionizing radiation sources must comply with any necessary requirements, specifically the Nuclear Regulatory Commission's Title 10 Code of Federal Regulations (CFR) and Florida Statute 10D.56 and must be used under the supervision of a state qualified radiation protection officer.

All leak checking using the helium containing the krypton-85 gas takes place within Building 1 in a sealed tent to preclude exposures within the building. The majority of the krypton is recovered and the remainder is vented out through an exhaust duct above the roof. The exhaust concentration is limited to $3x10^{-7}$ millicuries per liter of air, which rapidly diffuses in the atmosphere and dissipates before reaching the facility boundary. The maximum amount of krypton-85 that could be released to the atmosphere, conservatively assuming a full day of leak checking with a continuous release at the maximum allowable concentration, corresponds to a dose of less than 2 millirems of radiation.[11] Therefore, there are no adverse health effects posed to the public. No other radiation sources have been or are scheduled to be used at the Astrotech facility.

4.4 Building 2 Features

The fueling operations at Astrotech by their nature require engineering controls and personal protective equipment that reduce any risk to systems and personnel within the facility to as low a level as is reasonably achievable. Although this safety evaluation does not focus on the risk to personnel within Building 2, controls that protect personnel also minimize risk to the general

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[10] Category A electro-explosive devices are those which, by expenditure of their own energy or because they initiate a chain of events, may cause injury or death to people or damage to property (Eastern Space and Missile Center, Range Safety, ESMCR 127-1, 30 July 1984, Section 3.13.2.2)

[11] This dose can be compared with radiation doses from other activities, e.g., flying from Los Angeles to Paris - 4.8 millirems; getting a chest x-ray - 22 millirems; getting a full-mouth dental x-ray - 910 millirems; and getting a mammogram - 1,500 millirems.

public and are therefore relevant. As described in this section, the controls include the design and construction of Building 2 as a "self-contained" facility, the spill containment system to preclude any release of liquid propellant from reaching the environment, and the scrubber system to reduce any point source propellant vapor emissions from normal operations. The containment and scrubber system work together to ensure that all vapors from the system are reduced to acceptable levels as detailed in Astrotech's Florida DER air permit. Standardized work practices and procedures (see Section 5), similar to those required at KSC and CCAFS, provide additional protection against unanticipated accidents or releases.

4.4.1 Propellant Containment and Scrubber System

It is essential while performing fueling operations to minimize the release of propellants. Astrotech has included special design features and operations procedures which can confine spilled propellant vapors within Building 2, continuously monitor vapor concentrations, and collect all fugitive and point source emissions (vapors and liquids) to chemically treat them. In the event of a spill (with no associated fire or explosion), Building 2 is designed to contain all propellant vapors and liquid and to prevent any release to the environment.

Containment Facility

Building 2 was designed and built from the very beginning to be a containment facility in case a release of propellant liquid or vapor should occur inside the building during routine operations. In the event of a large fuel spill, defined as a spill of greater than one gallon, the personnel in the high bay would evacuate the building, the personnel in the control room would turn off all power (effectively sealing the building) before evacuating, and no one would reenter until the ambient concentration of the propellant vapors decreased sufficiently to allow reentry.[12]

The rate of decrease of fuel vapor concentration can be predicted using the hydrazine "half-life" concept that is based on laboratory studies and detailed by Schmidt in a book titled Hydrazine and Its Derivatives. Hydrazines react with oxygen, carbon dioxide and water in the air aided by agitation and recirculation. Half of the initial volume of anhydrous hydrazine and monomethyl hydrazine breaks down into non-toxic constituents in roughly 1 hour and 3 hours, respectively, as presented in Exhibit 4-6. The evaporation rates are also listed in Exhibit 4-6 as relative indicators of the volatility of the fuels.

EXHIBIT 4-6 HALF-LIFE TIME AND EVAPORATION RATES

A recirculation fan inside Building 2 can circulate any vapors within the building to promote agitation and evaporation and therefore, a more rapid decay. The self-contained recirculation fan disperses and dilutes vapors and, in instances of releases of fuel, will assist in the natural "half-life" deterioration of the fuel vapors. Vapor circulation can be further assisted by opening internal doors between the high bays and airlocks, thus allowing greater volume of air within the sealed facility to mix with the vapor and break down the concentration of fuel vapor (see discussion below).

Vapor Monitoring

At all times that liquid propellants are in Building 2, vapor detectors

[12] Communication with Astrotech, 1990.

Compound	Evap. Rate ($mg\ cm^{-2}\ min^{-1}$)	Half-Life Time* Air (hours)	Water (days)
Anhydrous Hydrazine	0.49	1.1	7
MMH	1.7	2.7	10

* Ch. 4 "Hydrazine Handling," p. 600, Hydrazine and Its Derivatives, Schmidt, 1984, Wiley and Sons, Inc.

are in use. During propellant loading operations, toxic vapor detectors and visual inspection of equipment are used to monitor the area. If a release is indicated (either by elevated concentrations of propellant [100 parts per billion {ppb} of anhydrous hydrazine; 200 ppb of monomethyl hydrazine; 3 parts per million {ppm} of nitrogen dioxide] or by visual observation of a liquid spill), the fueling team would turn off valves to stop propellant flow and to minimize damage to the spacecraft and other equipment.

Astrotech has recently obtained state-of-the-art toxic vapor detectors to supplement and ultimately replace a less sophisticated vapor analysis system (Draeger Tubes) traditionally used, and has incorporated their use in revised operating procedures. The increased sensitivity of the new detectors will improve safety by alerting personnel more quickly of elevated vapor concentrations. The detectors combine the use of special detection tape keyed to the material being monitored and microprocessor control for speed, accuracy and specificity. These detectors are portable and are encased in special explosion proof clear plastic cases. A concentration alarm is indicated by a continuous tone and steady alarm light emitting diode (LED). Instrument problems (e.g., bad battery, tape break) are indicated by a flashing red indicator and an intermittent beep, and the alarm relay will be activated. These detectors have factory set alarm levels available of 200 or 400 ppb for MMH, 100 or 200 ppb for N_2H_4, and 3 ppm or 6 ppm for NO_2[13]. Astrotech monitors at the lower concentrations. More general instrument specification information on the new MDA portable toxic gas detector can be found in Appendix C.

Trenched Fueling Islands

Propellant transfer and loading operations take place in the center of the high bays on a 25 feet by 25 feet "fueling island" created by a stainless steel trench which surrounds a center portion of the floor. The trench is covered by stainless steel grating and slopes to a common point where it drains into the containment system located underground immediately outside the building. The trench drainage system would confine a spill and facilitate cleanup operations. In the event of a spill of fuel that resulted in a fire, the trench system would also confine the fire to the fueling island and prevent spread of the fire to any other area of the high bay or the adjoining rooms.

Containment and Neutralization System

[13] Guide To Operation, TLD - 1 Toxic Gas Detector, MDA Scientific, Inc., 1989.

The Astrotech waste containment and neutralization system serves both oxidizer and fuel propellant loading operations. Any propellants (liquid or vapor phase) released or spilled in Building 2 are processed through this system. This containment system is comprised of two underground holding tanks and a vapor scrubber (see discussion below). These tanks collect any liquid spillage which could occur during propellant sampling and transfer operations. Each tank (one dedicated for oxidizer and one dedicated for fuel) has a capacity of 6,100 gallons and contains approximately 500 to 1,000 gallons of water mixed with the appropriate neutralizing agent before the start of a propellant loading operation. A common piping system leads from the fueling island trenches to a T-valve upstream from the holding tanks. The piping drawing, examined by the evaluation team, showed that the drain line is a 4 inch, 110 cubic feet per minute (i.e., 50 gallons per minute [gpm]) line. The valve must be manually operated to connect the trench with either the fuel or oxidizer tank, depending on the propellant operation. Floor drains in the propellant cart rooms also drain into the holding tanks, either directly (in the case of oxidizer) or via the trench drain (for the fuel).

The tanks are constructed of fiberglass reinforced polyethylene with an inert lining. No secondary containment or monitoring wells are required around the tanks or lines. Hunter/ESE (an environmental engineering consulting firm) performs annual leak checks on the tanks. In addition, the City of Titusville can sample the tanks at any time to confirm that no hazardous substances are stored. Recently, the City has been sampling the tanks regularly and has never found a problem with Astrotech's use of the tanks. The tanks are buried in the ground by tying them to underground concrete pads, to keep them from "floating" in the buoyant soil. DOT placards indicating hazards of the contents are posted above each of the tanks.

After loading operations are completed, hose lines are aspirated clean using suction to draw any vapors or residual liquid into the containment/scrubber system. Then, the hose lines are capped and bagged for transport and decontamination by the customer. Any excess fuel or oxidizer is returned to CCAFS. The propellant loading carts which are used to condition propellant and then to load the spacecraft are cleaned on-site or the customer may send the entire cart off-site for cleaning once he has demonstrated full compliance with all applicable DOT transport requirements. The filter system used for the transfer of nitrogen tetroxide is cleaned with freon.

Any hazardous waste that must be disposed is packaged and labelled in accordance with EPA hazardous waste regulations and manifested for transport according to DOT regulations. Installation of a closed-loop distillation system is planned. This system will further minimize the generation of hazardous waste by allowing the freon to be recycled.

The waste propellant vapor and liquid aspirated into the underground containment tanks are then neutralized into non-toxic products in preparation for discharge to the sewer. Anhydrous hydrazine and monomethyl hydrazine are neutralized with calcium hypochlorite (HTH) and the neutralized liquid in the tank is checked for approximately 1% residual chlorine as an indication of destruction of all hydrazine. N_2O_4 is neutralized with sodium hydroxide (NaOH) to a pH of 10 to 12.

The neutralized liquid is pumped to the scrubber agitator tanks before discharge to the Titusville city sewer. The city first samples the material and tests for biological oxygen demand, chemical oxygen demand, and extraction procedure toxicity parameters (mostly metals and pesticides). When the city determines that the waste water presents no hazards to the treatment facility, the waste water is allowed to be discharged and is then processed through the sewage treatment system, commonly known as a Publicly Owned Treatment Works. The average amount discharged per spacecraft processing operation is about

5,000 gallons. A discharge is made after every complete spacecraft loading operation. The current annual processing rate of six payloads results in six discharges per year.

Vapor Scrubber

The scrubber functions during normal operations as an air pollution control device by treating any fugitive or point source emissions of propellant vapor, so that the emissions to the environment meet the Florida DER air quality permit requirements. Stray vapor is drawn out of the building through flexible hoselines and goes through the containment tanks into the scrubber columns. The propellant reacts with the scrubber liquid and is removed (or "scrubbed") from the vapor phase. The scrubber is not designed to handle a catastrophic spill or accident but rather to treat point source and fugitive emissions generated within Building 2 during normal propellant transfer, sampling and loading operations.

The scrubber consists of two 40 foot packed bed towers that operate in series using counter-current flow with an approximate 10 inch drop. In each bay there are two 2½ inch ports (facility vents) located on opposite walls (north and south). During sampling or fueling operations, a dedicated flexible hose (for either oxidizer or fuel) is attached to the nearest port and directed in the close vicinity of the operation to remove any stray vapors. These vapors are first drawn by a fan to the holding tanks and then the tank vapor is taken through the scrubber. The centrifugal fan in the scrubber system, which was activated while the evaluation team was inspecting it, draws a vacuum through the tanks and to the ports in the high bays. The vacuum draws any fugitive or point source emissions out of the building to be treated. Once the vapors are scrubbed, the exhaust is discharged into the atmosphere through a five inch diameter stack 60 feet above grade.

The scrubber stack parameters[14] include:

Exhaust flow rate	400 actual cubic feet per minute (acfm)
Exhaust temperature	70.7 degrees Fahrenheit (annual average)
Scrubber efficiency	90%
Stack diameter	0.42 feet
Standard conditions	68 degrees Fahrenheit; 29.92 pounds per square inch actual (psia)

The scrubber is located within the lightning protection of Building 2 as detailed in Section 4.4.2. Because there is no back-up power supply to the scrubber system in case of a power outage, the scrubber would automatically be turned off, sealing the building. In the event of a large spill, the building would be evacuated and the power to the building including the scrubber would be turned off from the control room, sealing the building.

The scrubber is designed to handle normal propellant loading operations involving either fuel or oxidizer. Scrubber liquors are sodium hydroxide in a 10% solution at a pH of 10-12 with sodium sulfide (Na_2S) for oxidizer and water for hydrazine fuels. Different liquors are needed depending on the vapors present, because the vapor undergoes a chemical reaction with the scrubbing liquor. The scrubbing liquor can be considered a sponge; just as a sponge can absorb a large, but limited amount of moisture, the liquor can absorb (i.e., react with) a limited amount of vapor. The treatment capacity of the scrubber liquor is more than adequate to handle normal propellant loading operations. The system can handle a total of 300 pounds of oxidizer

[14] Satellite Fueling Operation Response to FDER Completeness Summary, Hunter/ESE, No. 3901-010010-0400-3160, July 1989.

and 100 pounds of hydrazine fuel without recharging the respective scrubber liquor.[15] This translates into approximately 25 gallons of oxidizer and about 12 gallons of fuel, which would be extremely large releases.

The vendor has further indicated that the scrubber exhausts approximately 100 ppm or less of NO_x vapors and has an average efficiency of 90%; therefore, an approximate 1,000 ppm charge of NO_x vapors can be scrubbed. Astrotech has indicated that the system can effectively handle a charge of approximately 200 ppm of fuel vapor and remain functional at maximum efficiency. If fuel vapor concentrations rise above 200 ppm, the scrubber could handle the higher concentration over a longer period of time. If a spill of sufficient magnitude occurs such that the scrubbing liquor became saturated, reducing its capability to react with propellant vapors, the liquor would be recharged and the scrubbing process resumed. It is important to note that the scrubber is not designed to handle emergency releases of propellant nor for use in decontaminating the building in the event of a spill although over a long enough period of time this could be effected.

The approximate magnitude of anhydrous hydrazine spilled that could reach 200 ppm depends on the air volume in the high bay or combination high bay(s) and airlocks available for dilution of the concentration within Building 2.[16] For example, in the south high bay (approximate volume of 95,460 cubic feet of air), it would take about 0.18 gallons (about 3 cups) of anhydrous hydrazine spilled to reach 200 ppm in the bay; however, in the event of a spill, the south airlock could also be opened, making an additional 42,920 cubic feet of air available. Then, approximately 0.25 gallons (about a quart) of anhydrous hydrazine would be required to be released to reach a concentration of 200 ppm. However, it must be noted that given the total capacity of the scrubber system, while it would take about 4 hours to process the 95,460 cubic feet of air containing the fuel vapor (or about 5.75 hours for the larger volume) at maximum efficiency, the system could obviously handle a larger release over a much longer time period before reaching saturation.

As a benchmark, the lower flammable limit (the vapor concentration which will ignite and burn in the presence of an external ignition source) of anhydrous hydrazine in air is 4.7 percent on a weight percent basis or 4,700 ppm; this limit for MMH is 2.5 percent or 2,500 ppm. At these levels in the high bay, fire would be the most serious hazard. The scrubber is not designed to handle releases of this magnitude.

4.4.2 Static Electricity Protection

Because flammable liquids and vapors can be present in Building 2 and because SRMs and EEDs are extremely sensitive to electrical discharge, significant design features and detailed operations procedures are in place to minimize the opportunity for spontaneous electrostatic discharge (i.e., sparks).

Electrostatic Dissipating Floor Tile

The floor covering in the high bays and North Airlock is made of a static dissipating, graphite impregnated, vinyl tile. The tile is bonded to a substrate with an electrically conductive mastic and connected to the

[15] Correspondence with Tri-Mer Corporation, Air Pollution Control Systems, manufacturer and supplier of the Astrotech scrubber system, August 1, 1990.

[16] This section discusses only vapor concentrations within Building 2. See Section 7 for a discussion of vapor concentration outside the facility.

grounding grid system. The fuel and oxidizer cart rooms and the South Airlock do not have conductive tile but do have fixed grounding points in each room. The conductive tile and grounding points prevent electrical sparks in Building 2.

Lightning Protection System and Operations Policy

The entire central Florida area is known for its high incidence of thunderstorm and lightning activity. The Astrotech facility is constructed with design features that ensure minimal negative effects in the event the facility is hit by lightning. (To date no building within the Astrotech facility has been struck by lightning.)

A lightning protection system surrounds Building 2 and consists of eight lightning masts approximately 100 feet high, each connected to the primary grounding grid, designed to prevent induced electrical current damage to all support equipment.

Prior to all hazardous operations, a Stormscope (a state-of-the-art, commercially available lightning detection system) is activated on site which receives radio frequency (RF) signals from electrical discharges in the atmosphere out to a distance of 200 miles from Building 2. If an electrical storm is indicated within five miles of the facility, Astrotech's policy is that no hazardous operations are initiated. Any ongoing hazardous operations may be stopped immediately or continued only until a stable stopping point is reached, depending upon the determination by the Astrotech Safety Officer and customer safety official. Because the Stormscope identifies storms out to 200 miles, the Safety Officer knows in advance of a storm's existence and can delay operations at his discretion if, for instance, a storm twenty miles away appears to be heading toward the facility. During ongoing operations, safety personnel are alerted by an audible alarm feature on the Stormscope to the presence of any lightning within 25 miles of the facility.

Explosion Proof Electrical Systems

All electrical supply and illumination systems operating in Building 2 are either explosion proof by design or are made explosion proof by purging the fixtures with an explosion preventing gas. The design requirements for these systems are in accordance with pertinent sections of the National Electric Code and NFPA Codes.[17] The codes require that conduit and outlets be sealed to preclude vapor entry, that all switching and contacting operations be in sealed enclosures and that exposed surface temperatures be limited to levels that will not produce vapor-air ignition. All electrical equipment, including lighting that cannot practicably be sealed, is purged, eliminating the possibility of vapor entry and subsequent exposure to potential electrical ignition sources.

Physical Separation of Equipment

Non-explosion proof electrical equipment must be kept at least ten feet away from any SRM assembly. Prior to starting any operations involving SRMs, the area is "safety checked" by both Astrotech and its customer. This requirement is also true for operations involving ordnance and liquid propellants.

Required Grounding Equipment

Grounding equipment, including such items as legstats, wriststats,

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[17] National Electric Code, 1987, which is Section 70 of the National Fire Codes.

conductive shoes, and shoe coverings, is required for personnel handling ordnance, working within five feet of exposed SRM propellant grain, handling propellants or working in a high bay containing a fueled cart or spacecraft. All grounding equipment is tested before each operation to ensure electrical resistance levels (i.e., between 0.01 and 1 megohm) that avoid the occurrence of sparks.

4.4.3 Personnel Protective Measures

Because the hazards associated with the handling of SRMs, PAMs, EEDs, ordnance, and propellants generally pose a danger only to personnel working in their immediate vicinity, non-essential personnel are not permitted near operations involving these items. Special design features and safety procedures protect personnel that are working in the immediate vicinity of these materials.

Area Clear Restrictions

Safety precautions and restrictions are established and enforced at Astrotech to limit the physical presence and access of non-essential personnel during hazardous operations. These physical access restrictions have been defined by Astrotech based upon operating expertise and requirements of several of their payload customers and extend to either a 10-foot radius from the activity to the entire room (high bay) in which the activity is taking place, to the entire hazardous section of the facility. In general, the relative risk associated with each operation is correlated with the size of its control area. The operations that take place within Building 2 and their control areas[18] are listed in Exhibit 4-7.

[18] Safety Standard Operating Procedure, 1988, Astrotech Space Operations, L.P.

EXHIBIT 4-7 AREA CLEAR REQUIREMENTS

OPERATIONS	CONTROL AREA
Clampband installation	10-foot radius around operation
Solid rocket motor ordnance installation/removal	10-foot radius around SRM
Spacecraft ordnance installation	10-foot radius around spacecraft (or greater at discretion of Spacecraft Manager)
Solid rocket motor handling and transfer	Active high bay in which work is being conducted. Work may continue in adjoining high bay(s)
Solid rocket motor grain inspection	Active high bay. Work may continue in adjoining high bay(s)
Solid rocket motor leak test	Active high bay. Work may continue in adjoining high bay(s)
Activation of Shuttle or PAM cradle spin system with PAM	Active high bay <u>and</u> adjoining high bays
Hoisting of solid rocket motor	Active high bay <u>and</u> adjoining high bays
Spin balance solid rocket motor	Active high bay <u>and</u> adjoining high bays
Spacecraft pressurization	Active high bay <u>and</u> adjoining bays
Liquid propellant transfer into spacecraft	<u>Entire</u> Building 2 with road block manned by Astrotech
Spin balance with loaded propellants in spacecraft	<u>Entire</u> Building 2 with road block manned by Astrotech

The transfer and loading of propellants and operations performed on fueled spacecraft require that Building 2 be cleared of all non-essential personnel. Access to the area surrounding the building is restricted; only personnel directly involved in safety monitoring or performance of the operation are permitted within the hazardous work area of the facility.

During "building clear" operations, access to Building 2 can be restricted by closing a gate arm near the badge house located a safe distance from the building. A safety monitor is positioned at the gate to limit access to the Building 2 area. Signs on the gate indicate "Keep Clear" and "Hazardous Area." The gate arm also has a yellow flashing light activated from inside the badge house. This badge house is manned by Astrotech personnel when hazardous fueling operations are taking place; it is equipped with telephone and power, and serves as the fallback assembly area in case of emergency evacuation of Building 2. A hazard status board located near the badge house indicates the nature and location of any hazardous material present in Buildings 2 or 3.

Procedures for installation of EEDs are another example of procedures to limit personnel exposure. EEDs may not be installed until a control area has been established and cleared of nonessential personnel. These devices must not be electrically connected to the spacecraft systems until a power on and off check is made to ensure there is no stray voltage. The control area is required to be defined in the operating test procedures provided by the customer to Astrotech. All personnel in the defined control area are required to wear protective clothing and grounding equipment.

Personal Protective Equipment

All personnel working in Building 2 when release of liquid propellant (fuel or oxidizer) or vapor is a possibility are provided with personal protective equipment (PPE). PPE is designed to protect an individual from toxic vapors and/or heat generated by fires and provides an appropriate air supply and air filtering system along with protective coverings (e.g., chemical resistant suit, boots, gloves). Equipment used at Astrotech meets NASA flammability and compatibility requirements for the hazards present. Level A, B or C equipment (as defined by the EPA) is available and meets Mine Safety and Health Administration/National Institute of Occupational Safety and Health (MSHA/NIOSH) standards and approval. The level of PPE required is dependent upon the nature of the operation and the potential hazards. For example, during operations where propellant vapors may be present (e.g., the leak check, propellant sampling and start of propellant loading operations) the highest level of protection, a Level A PPE[19], is worn. However, once the closed loop fueling operation has been verified to be leak tight, personnel can change into a Level C (splash suit)[20] for the remainder of the fueling operation. If a problem is indicated, the crew can change into Level A and re-enter to monitor the situation and take appropriate actions.

Breathing Air System

In Building 2, air is purified through a compressed air purification system that removes particulates, water vapor, and carbon monoxide (CO). A downstream remote alarm system continuously monitors for CO. In addition, a reserve air system has the capacity to allow four users at least five minutes to exit and decontaminate. Further, a five minute emergency air supply is incorporated into the air line respirator apparatus, allowing the user to disconnect from the air line umbilical to exit and decontaminate with a self-contained breathing apparatus (SCBA). The emergency breathing air system can be independently connected to a 50 kVA diesel power generator as a standby power source in case of a general power failure.

During emergency escape from Building 2, individuals could also take advantage of an Emergency Life Support Apparatus (ELSA). These portable, self-contained breathing units provide air for five minutes in oxygen deficient or contaminated atmospheres and are easily accessible to workers in both the North and South high bays.

Remote Visual Observation

Remote visual monitoring enables individuals, like the Astrotech Safety Officer and customer safety personnel, who must directly observe hazardous activities to do so without being in the immediate presence of the hazard. In Building 2, explosion-proof observation windows installed between the control

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[19] Level A PPE includes a supplied air respirator with an auxiliary self-contained 5 minute emergency air supply; a SCBA with full facepiece; fully-encapsulated chemical resistant suit; chemical resistant inner and outer gloves; chemical resistant boots; and two-way OIS communications and umbilical.

[20] Level C PPE includes chemical resistant disposable overalls; chemical resistant outer gloves; and 5 minute Emergency Life Support Apparatus (ELSA).

rooms and the high bays allow Astrotech and customer payload safety officers and quality control personnel to observe hazardous operations directly. Thus, safety officers can validate compliance with procedures, but minimize risk to themselves and eliminate any potential interference with operations that their presence in the high bay might cause.

In addition, there are five closed circuit television (CCTV) cameras for remote monitoring of operations in Building 2. However, these cameras currently have no scanning or zoom capabilities. All three Building 2 high bays can be monitored by video camera. Videotapes of fueling operations are routinely made by Astrotech and offered to customers; video monitors can be set up during fueling operations. Thus, any individual that needs to see observations performed, but who does not need to provide direct feedback during those operations, can either watch a monitor located in Building 1 during the ongoing operation, or can watch a videotape later.

4.4.4 Monitoring Systems and Communications

In order to ensure that equipment is functioning properly, as well as to provide prompt response to any potential emergency, Building 2 is equipped with detection and monitoring systems that alert the control rooms and the guard house, as appropriate, of significant changes in the facility status. Communications during operations exist between the working area, the control room and the guard house.

Building 2 is also equipped with an explosion-proof paging system that can be used from either of the two control rooms. The paging loudspeakers are located in all high bays and airlocks. The emergency exits in Building 2, which shut automatically after opening, are also equipped with emergency communication equipment that sounds a local alarm when activated.

Alarms are automatically sent to the guard house via computer link for various parameters identified below (additional capacity in the computer link is available to accommodate additional monitoring system alarms in the future). The guard house alarm panel was recently installed by Honeywell.

<u>Parameters Monitored</u>

1. Temperature and humidity (HVAC systems)
2. Loss of pressure to fire protection system (i.e., compressor failure)
3. Toxic gas detectors and detector status (i.e., tape break or battery problem)
4. Generator failure
5. Fire alarm

Also, a fire alarm is sent to the Titusville fire department via automatic dialup.[21]

Non-hazardous situations can cause alarms. For example, item 2 on the above list would alarm if the compressor failed. At that time, there would be no immediate danger to the facility. However, the pre-action fire suppression system (see description below), if needed, would require monitoring for loss of pressure. Similarly, equipment problems with the gas detectors would not in themselves be a hazard; however, their malfunction would limit the ability of safety personnel to detect a hazardous atmosphere. If such an alarm occurred during hazardous operations, operations would be brought to a stable stopping point, personnel evacuated and the source of the alarm investigated.

Temperature and Humidity

Both temperature and humidity are monitored in the high bays to ensure safe levels and effective functioning of the HVAC system. The typical control settings are 70°F and 50 percent humidity with alarms at 60 percent relative humidity and 75°F. The target levels and alarm settings for temperature and humidity are designed to protect sensitive spacecraft equipment from damage and can be specified by individual customers, as required. However, Astrotech will not allow hazardous operations to take place if the relative humidity is below 30% due to electrostatic hazards at humidity lower than this level.

Vapor Monitoring System See Section 4.4.1

Fire Alarm and Sprinkler System

The pre-action fire protection system[22] is a computer-controlled system designed to quickly extinguish any fire within Building 2 while protecting spacecraft and other valuable equipment from inadvertent system activation or malfunction. The high bays and airlocks have a dry-pipe solenoid actuated system.[23] The piping between a valve and the sprinkler heads is pressurized and the pressure level monitored to ensure no loss of pressure. In order to get water to the sprinkler head two things must occur: a smoke/heat detector (see description below) must indicate a problem or a manual pull station must be activated and the fusible link on a sprinkler head must melt due to an intense heat source (the link melts at approximately 155°F).

For areas of the Astrotech facility where immediate danger of damage to equipment from inadvertent wetting is not as great (i.e., non-high bay, non-airlock rooms in Buildings 1 and 2 and all other buildings), there is a wet-pipe system with automatic sprinklers connected directly to a water supply, that discharges water immediately upon melting of the fusible link at the sprinkler head.

All water is supplied from the Titusville municipal system and is assisted by a diesel boost pump, located in the pumphouse at the front of the property, that upon system activation automatically provides 1,500 gpm of water at 150 psi pressure. The North and South high bays in Building 2 each have 28 sprinkler heads with 5/16" orifices and fusible plug activation temperature of 155°F; the smaller center spin bay has 15 sprinklers; the airlocks each have 12 sprinklers. Rough estimates of flow from each sprinkler

[21] Safety Standard Operating Procedure, Astrotech Space Operations, L.P., 1988.

[22] For additional information on fire protection systems see NFPA Fire Protection Handbook, 14th edition.

[23] The high bays and airlocks in Building 1 have a similar pre-action fire suppression system.

range from 40 to 50 gpm. If all 28 heads in a Building 2 high bay were open, the total flow would be approximately 1,260 gpm.

All areas in Building 2 have ceiling-mounted infrared (IR) smoke/heat detectors that detect rate of heat/rate of rise. There are six detectors in each high bay and two detectors in each of the return lines of the HVAC system. There are also thermo-couples mounted on the tanks of the propellant loading cart and in the spacecraft to monitor temperature during fueling.

There are portable fire extinguishers of both halon and dry chemical types located throughout the facility.

Generator Failure See Section 4.4.6

Communications During Operations

There is a manually activated intercom (i.e., push-to-talk) for communication between the control room and the fueling team during propellant loading operations. Also, hand-held communication boards that can be written on are available. As mentioned above, Building 2 is equipped with an explosion-proof area paging system that can be used from either of the two high bay control rooms.

The guard house is the focal point for the communications and alarm detection system as described above. There is a cellular telephone and eight UHF radios available at Astrotech for use by staff. In the event of an incident, the guard has a list of personnel (with phone and pager numbers) to be notified. See Section 6.0 for additional detail on emergency communications.

4.4.5 Hurricane Potential and Restrictions

The potential for hurricanes during the wet season is well known; the facility continuously monitors the likelihood of hurricanes approaching, and implements hurricane preparation procedures whenever necessary. In addition to implementation of specific procedures, buildings on the Astrotech site are designed and constructed to withstand sustained winds of 125 miles per hour. Since 1887 only 24 hurricanes have passed within 100 nautical miles of KSC and CCAFS. None have entered the Cape Canaveral area. However, hurricane precautions are taken seriously, not only to protect valuable flight hardware elements and operations facilities but also to ensure worker and public safety.

Weather tracking, specifically hurricane prediction, for the immediate vicinity is meticulously performed by the U.S. Air Force meteorologists at CCAFS with support from the National Weather Service. In its MOU with NASA, Astrotech can contact NASA by telephone at anytime for weather information. In addition, contractor teams stationed at the facility are automatically alerted by the Air Force of potential hurricanes.

Astrotech's hurricane precautions are patterned after those used at CCAFS and KSC.[24] They include successive steps of preparations for the strong winds and heavy rains. For example, building evacuation and sandbagging of entrances begins 24 hours before winds of 50 knots (57 miles per hour) are expected to reach the area. In addition, all "unhardened" temporary or portable structures are generally secured by anchors or removed and stowed, as are any loose construction materials.

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[24] Hurricane Preparedness Implementation Plan, NASA/KSC, KHB-1040.2

4.4.6 Backup Power

Florida Power and Light is the prime provider of power to Astrotech. In case of an unanticipated power failure, each building has a sensing device and power automatically switches over to a 25 kVA propane-powered generator. The backup power to Building 2 is fueled by an external propane tank mounted outside the generator room. The automatic power supply initially goes only to emergency lighting in the high bays. This light level was tested during the on-site visit and found to be sufficient for any kind of emergency operation. The cranes and the airlock roll-up doors can also be powered from the backup generator, so that if a spacecraft was being lifted during a power failure, the lift could be completed. Manual relays must be thrown in the generator room to direct power to the cranes or to the doors.

There is also a 55-kw diesel generator that can be plugged in and used during count-down and for power up during ground stations and spacecraft checkout. (A 50 hertz source is available for European satellites). There are also several uninterruptable power supplies available to prevent software crashes during system testing and checkout.

Building 2 has battery backup for the fire protection system and the portable toxic vapor detectors; however, there is no backup power provided for the scrubber system. This could negatively impact ongoing fuel operations in the event of a power failure, especially during sampling operations, allowing vapors to build up in the bay. It could also impact emergency response activities since access to the building could be restricted because of dangerous concentration levels with no system to remove the vapors. However, since the scrubber was not meant to serve as an emergency system and is not designed to handle large spills, the fact that it receives no power in the event of a failure caused by a catastrophic accident is a protective measure to ensure that no untreated vapors are exhausted directly to the atmosphere from a scrubber system not designed or intended to treat them.